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## GROUNDWATER: ALTERNATIVES AND SOLUTIONS

Fred Roach  
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### Introduction

The generic "water and energy" question has been with us for some time. However, the debate over the availability of water for energy extraction and conversion has intensified since the 1973 Arab oil embargo. Water is an input to the energy production process, and, therefore, the general concerns about resource scarcity are as applicable to water as they are to the supplies of oil. These concerns over water availability can easily be traced back to the time when our country was first being forged out of the North American continent. The need for water increased greatly as the country entered the industrial age of the 1800s. At that time, though, the use of water in the energy processes was somewhat different than it is today. Often, water itself was the source of energy (for example, small scale hydro and grain mills), as well as serving as a transfer medium (for example, the steam locomotive).

Water availability for energy is not a geographically centralized concern, although much of the present debate is focused on the West. In the East, the question of water availability is receiving increased attention as both demand for streamflows and water quality issues play larger roles in economic growth. In addition, shortages of water supplies for energy growth have been projected recently by several major studies. In this short paper, I will focus my attention on (1) the question of water availability for energy development and (2) the potential role that groundwater and other alternative sources of supply (where unappropriated and easily transferable/obtainable surface supplies are and have been delegated the "traditional" source of energy's water requirements) may play in the future.

## The "Water and Energy" Question

The question of water availability for energy will not disappear nor will it decrease in relative importance. On the contrary, it is likely to become an ever larger concern as domestic energy production is stepped up to meet national goals and as attempts are made to lessen dependence on foreign energy supplies (especially oil). The synfuels initiatives have given rise to renewed questioning of water supplies for energy: both as to their physical and institutional availability, and as to their appropriate use. That is, should energy be allowed access to water at the "expense" of other economic and possibly more importantly noneconomic users of those same supplies? Recent concerns by both the North Dakota and South Dakota Governors about the proposed coal gasification plant near Beulah, North Dakota, combined with similar concerns voiced by other individuals and groups in the same region raise a number of issues over the future of water availability for synfuels in general. These issues, concerns, and questions of water availability for energy are going to be asked far more frequently and by more knowledgeable persons than has been true in the past. Increased emotionalism in this area is going to make it difficult to provide appropriate and acceptable responses to questions of real water availability for the energy industry.

This notion of emotionalism is increasingly important for the energy industry: in the West, where it has been recognized for the same time; and in the East, where water resource problems are now being acknowledged. Although a lot of other users will be making claims on the scarce water supplies, the energy industry itself is viewed with great suspicion because it requires a relatively large amount at single sites and it is the newest entrant in the competition for these scarce supplies. Water's increasing value gives rise to numerous questions. How much is the water really worth? How much is left?

Where is it located and who should (or can) have access to it? When is that access to be granted?

At the American Water Resources Conference held last Fall (1979) in Las Vegas, Nevada, I presented a paper on the "water and energy" question. The general conclusion of the paper, a rather novel idea at the time in the sense of being public about it, was that water availability per se would not act as an absolute constraint to energy development. That is not to say that the question of water availability was not important--that there would be no conflicts or impacts, or that locational decisions would not be affected--but, rather, that water supplies would be available to support energy at the levels presently envisioned for the turn of the century. The reason I state that this idea was novel is that, generally, it had been concluded that water supplies were inadequate to support energy development at the then projected levels needed in the 1980s and 1990s.

For the most part, the use of unappropriated surface waters (and, at times, transfers from present agricultural users) was the only supply option examined. Demand projections and hence supply requirements were predicated on historical trends (usually oil pre-embargo), thus leading to relatively large quantities of energy being produced (extracted and/or converted) in the West. Large quantities of energy led to large needs for cooling waters, and thus greatly increasing demands for already scarce western surface waters. Most studies addressing the "water and energy" question were remiss in their failure to more forcibly state their major premises and assumptions, as well as exclude from their analysis the alternative sources of water (and this includes demand substitution). In part, this failure has contributed to the abuse levied against the principal findings of these studies. Beginning in late 1974 to the present, one gets the feeling most "energy and water" studies

have concluded that water will absolutely constrain (at least partially) energy development. Articles carried in such prestigious publications as the Wall Street Journal, Washington Post, New York Times, and the Christian Science Monitor, as well as statements made by our distinguished Western Governors, lead one to conclude that the water supplies will not be adequate to meet the needs of our country's growing demand for energy. They have stressed that the water availability question is the principal and possibly final constraint or restriction to further development of energy resources in our region (the West).

As stated above, this belief is unfortunate because it is not true. But because of the focus of these studies and their concentration solely on the surface supply option, one can easily understand why such a conclusion could be drawn. When this conclusion is coupled with the increased emotionalism alluded to earlier, it is not difficult to see why water is playing an increasingly important role in assessments of energy supply projections.

I should disgress here for a second to acknowledge recent contributions in the "energy and water" question. The Department of Energy's (DOE) draft environmental statement on increased synfuels production, the Water Resources Council's supported studies for Sec. 13(a) review of the Upper Colorado and Missouri River Basins, and several reports prepared for DOE by the National Laboratories have recognized not only other potential sources of water supply for energy, but have lowered total water demands through more realistic assessment of future energy demands, energy-related water requirements, and the possibility of demand substitution. For instance, groundwater is viewed as potentially playing a major role in energy growth, although these reports quickly point out that its role is uncertain at this time.

### Past "Water and Energy" Studies

In the previous presentation by Dr. Hudson, a number of completed "water and energy" studies (1974-1979) were reviewed. Figure 1 identifies some of these studies that I have had the opportunity to review again. I have attempted to extract from these studies what has been said about groundwater. In addition to the studies listed in Fig. 1 and the others discussed previously by Dr. Hudson, DOE's Office of Technology Impacts has conducted a number of assessments where the "water for energy" issue was one of intense interest. For a number of other studies prepared by or for DOE in which the principal focus was on either energy development itself and/or the environmental consequences of expanded energy production, the issue of "water for energy" commanded much attention in their overall analysis.

From information contained in the above-mentioned studies, I can draw no other conclusion (notwithstanding my previous discussion on lack of an absolute constraint) but that the interface between water availability and energy development is and will continue to be fraught with problems and conflicts. The University of Oklahoma study (funded by the Environmental Protection Agency) makes it explicitly clear that water supplies will most likely be insufficient to meet all future demands placed upon them. Thus, increased conflict and competition for scarce water supplies will be the situation facing the energy industry as we move into the decade of the 1980s. The previous studies taken as a whole and coupled with promulgations in the popular press lead one to a very negative posture on the "water and energy" question. Moreover, a very frightening feeling develops that energy is persistently going to face severe and continual problems in its quest for needed water supplies.

FIGURE 1

PAST STUDIES

DEPARTMENT OF INTERIOR

WATER RESOURCES COUNCIL

ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION

FEDERAL ENERGY ADMINISTRATION

DEPARTMENT OF ENERGY

ENVIRONMENTAL PROTECTION AGENCY

STANFORD RESEARCH INSTITUTE

CONAES

OAK RIDGE NATIONAL LABORATORY

## Future Water Concerns

Figure 2 summarizes what I believe to be some of the reasons there are legitimate concerns about future supplies of water for energy. For the most part, these were drawn from previous "water and energy" studies and represent a synopsis of problem areas envisioned for energy, especially in the water-scarce regions. The concerns/problem areas address the traditional source of water for energy: surface water--primarily unappropriated stream-flows but also transfers from present agricultural users. They also reflect the general thinking that has led to the following conclusion: that water for energy is going to be a several and at times a binding constraint to the future development of energy supplies in this nation.

### Physical Availability

The first reason addresses pure physical availability. Annual and seasonal availability (stream-flows) of the traditional surface supplies will come under increased pressure from growing economic industrialization, rapidly expanding population bases, and, for the East, the use of irrigation technologies. In the West, there is a very complex seasonal problem even during good water years, with the present low snowpack in the higher elevations likely to bring this to another crisis situation in the Southwest this year. Fortunately, there appears to be adequate storage to meet many of the needs in most regions of the West. But, when two relatively dry years occur back-to-back, there is a significant drop in the acre-ft of water available for allocation. Competition for available streamflows (and associated storage volumes) increases dramatically, conflicts heightens, and the fervor of emotionalism again comes into play. This sequence of events has played many times in the West and will continue to do so with more regularity as allocations (appropriation in the real sense) approach or surpass surface



## FIGURE 2

### WHY WATER SUPPLIES A PROBLEM

#### PHYSICAL AVAILABILITY

ANNUAL

SEASONAL

#### TRADITIONAL UNCERTAINTIES

WATER RIGHTS

PRIORITIES

RESTRICTIONS

INCREASED COMPETITION/CONFLICTS

#### EMERGING CONCERNS

INDIAN RESERVED RIGHTS

FEDERAL RESERVED RIGHTS

INSTREAM VALUES

QUALITY

HABITAT

ENDANGERED SPECIES

RECREATION

AESTHETICS

WILD AND SCENIC-RIVERS

SALINITY MORATORIUMS

COURT CHALLENGES

#### EMOTIONAL ISSUES

DESTRUCTION OF LIFESTYLES

INCREASED PRICES FOR AGRICULTURE

availability. These same events probably will soon become true for portions of the East. Shortages of water supplies, whether real or perceived, will give rise to greater scrutiny of new users and uses of these scarce reserves. Energy, the new entry into this game--either because it is truly new or because of its greatly-expanded needs and hence potential share of total supplies--will be centered out for attention. More and more, public attention will play a stronger role in the siting of newly-proposed energy facilities.

#### Uncertain Availability

A second reason for this heightened concern over water availabilities for energy addresses traditional uncertainties. These include the water rights themselves, priorities associated with either acquisition or transfer of streamflows (this also includes storage rights), restrictions or prohibitions placed upon the surface waters, and the consequences associated with increased competition and more frequent conflicts. In the West, there are priorities that legally and administratively govern both the acquisition of unappropriated water (given one can actually locate these supplies) and the transfer from present owners/users. These recently-established priority systems generally have not benefitted energy, for they have delegated energy to a lower ranking than other present users, thereby making it extremely difficult, if not impossible, to acquire and/or transfer surface waters. Further, restrictions in some states have been placed upon the use of newly-acquired or -transferred water. These restrictions have taken many forms but certainly influence to what use that water may be put, where one is able to move or transport it, and what quantities may be used. The 15 cfs restriction in Montana comes to mind. Although the acquisition and transfer of surface waters has not changed greatly in a number of states, there is growing uncertainty about the future of presently conducive institutional climates to the use of water by energy.

Of course, increased conflicts and competition for surface supplies will measurably increase the visibility of energy's attempt to acquire (or transfer) water supplies in many regions. As stated earlier, the increased visibility usually results in larger uncertainties for the energy enterprise about the final outcome of its request for water supplies. Thus, there has been and will continue to be a growing reluctance to become involved in water resource acquisition where there are or is a potential for a large number of other users.

#### Emerging Availability Restrictions

A third reason for water availability concern is hinged upon the emerging streamflow issues. Reserved rights and their final determination certainly will have a bearing upon the future owners of water, if not their uses. For most energy entities (for example, coal companies and utilities) dealing with the spectrum of possible outcomes associated with any resolution (including status quo) of the Indian and Federal reserved rights question is extremely difficult. These rights have not been quantified, and are not likely to be quantified soon. Uncertainty and a high degree of risk in some areas have lessened the attractiveness of surface supplies.

The whole area of instream values is just now becoming recognized for its series of problems facing, first, future users (new) of surface waters and, second, many of those present users. Water quality and low flow maintenance in the East has been a concern for sometime, one that has led to questions about the adequacy of future streamflows to meet projected demands. The Riparian Doctrine of these Eastern States itself increased uncertainties about the firm availability of needed water supplies for energy. Other items addressed by instream values include protection of the present and future habitat of endangered species (Dr. Hudson earlier listed a few species

inhabiting some of our more likely sources of surface water supplies), and the whole gamut of recreational and aesthetic needs associated with instream flows. There has already been a few cases in which protection of endangered species--or more importantly from the standpoint of water use, their habitat--has put in question the potential use of surface supplies by energy. One such case involves whooping crane habitat in the state of Nebraska (Upper Missouri River Basin), and another the woundfin minnow in the Virgin River of Nevada. Increased population (ironically, much of it caused by rapidly-expanding energy development) will place greater recreational and aesthetic burdens on present water supplies. More water will be needed to support that growing population and associated nonenergy economic activity, thereby further lessening available water supplies for energy.

Designation of stream reaches as part of our national and, in a few instances, state Wild and Scenic Rivers will further close surface flows to use by the energy industry. Salinity moratoriums, such as the one on the Colorado River System, may act to further restrict the availability of streamflows for energy expansion. Legal challenges through our judicial or court system to the use of water by energy have grown in numbers, not only in the West but in the East as well. A legal challenge to an energy project has become an increasingly-popular sport for a great many environmental or pseudo-environmental groups. These challenges at times have used the water availability issue as their entry into the whole siting question. All of these emerging issues serve to further reduce the attractiveness, if not the actual availability of traditional surface supplies.

#### Emotionalism

Finally, the fourth reason for concern (and I believe most important one for the near future) is emotionalism. In the West, the taking of water from

present or future agricultural uses many times is believed to be inherently bad, that is, destroying something good in our lives, our heritage, even our lifestyles. The rather simple lifestyle (at least perceived in that fashion) is something that must be preserved; if not for ourselves, then for future generations. Energy's use of scarce surface water will displace other users (that is a fact whether it be present or potential users), and those other users have a high value to many. Thus, energy's pursuit of the traditional surface supplies to meet its demands leads to growing fears of destroying a western lifestyle.

A new variant of the emotional issue involves the price of agricultural water. Energy is big bucks and can afford to pay handsomely for its water supplies. By buying agricultural water at these "inflated" prices, costs are driven up for future purchasers of other agricultural waters. In the Great Plains region, as well as in other portions of the Rocky Mountain West, the energy industry has raised the price of irrigated water to the point of restricting future agricultural purchases of that same water. On economic efficiency grounds, nothing has been violated; water moves to its highest valued (that term would be severely questioned by many) use in the region. However, many other criteria are involved in an individual's evaluation of what is best for the region. Economic efficiency, even if measured in an absolutely correct manner, may not be viewed as the proper allocation mechanism. (This is evidenced particularly by the increasingly restrictive institutional climate being faced by the energy industry in its search for fresh surface waters to meet demands.) Emotionalism begins to enter the evaluation procedure as other (than efficiency) criteria are examined or as discussion centers on what values are to be used in assessing energy's economic right to the water.

## Water Acquisition

Adding to the difficulty of acquiring surface waters, at least in the West, is the complexity of pulling together water rights that may then subsequently be exercised to meet energy's demand requirements. In all states, there is a "public interest" right that must be assessed. In some stream regimes, that public interest may taken on instream flow reservations or it may take on a formal review process for new acquisitions and transfers. Instream values are increasingly being recognized, thereby further restricting physically available supplies. There are a very large number of paper filings--requests for appropriation that have never been permitted nor "proved" in any fashion--that must be evaluated carefully by any potential new appropriator of water in the West. In fact, if the paper filings were added for each stream system in the West, it is very probably that their aggregate quantity would warrant a transfer of water equal to one of the Great Lakes on an annual basis. Further, just locating all filings for water in a particular basin may be very difficult.

Public interest also is playing a larger role in the review of new applications for appropriation or transfer from present users. For energy, this generally will mean another review of its request for water supplies. In some states, the question of best use of that requested water is being asked far more frequently than in the past. More specifically, is energy the best use of that water? This opens the door for water to be used as siting constraint. Water is viewed as the vehicle to public questioning (and, in some instances, restriction on actual sites) of energy facility location.

## Problem Solution

Although I purposely have painted a gloomy picture for the generic "water and energy" question, it is also true that the traditional use of surface

supplies for energy production will come under increasing attack as development proceeds--both in the West and in the East. Groundwater has been acknowledged as a possible alternative or option by many, but unfortunately, it was generally as an afterthought. The principal focus of these studies or inquiries was the availability of surface water supplies for energy, with the general conclusion that shortages would occur. There was no question of shortage among these studies, only the timing and extent of the shortage was in dispute. Groundwater offers a far more promising alternative to traditional surface supplies and solution possibilities to the generic "water and energy" question than has previously been acknowledged.

There have been several recently-completed studies by the Los Alamos Scientific Laboratory (LASL) attempting to document the use of groundwater by the energy industry (although that was not the principal focus of any of these studies). Moreover, there are several other ongoing studies by LASL, other National Laboratories, and private research firms examining the potential role of groundwater in the whole water procurement process. Information from these past studies shows that at least the electric utility sector has been acquiring water from groundwater aquifers (for example, both the Cholla and Coronado generating stations in Eastern Arizona). In addition to the electricity generating facilities, a number of coal and uranium mines have used groundwater to meet their needs for quite sometime. That groundwater is becoming more "fashionable" (or mandatory, in some cases) is evidenced by its increased use in recent environmental impact assessments, statements, and reports for major energy developments. This is especially true in Arizona, Colorado, Texas, and to a lesser extent in the Great Basin region of Utah and Nevada. The recently-completed (Sec. 13(a)) study for Colorado provides an expanded recognition of the potential use of groundwater (although surface

water was the principal source and focus of that study). The potential for groundwater use by energy has been more actively discussed in the Upper Missouri River Basin. The prime synfuels development areas also are examining groundwater potential, albeit for supplemental supply at this point. But supplemental supply is the first step toward primary supply.

One may ask, then, if there has been and continues to be this use of groundwater for energy production, why hasn't it been more fully recognized in any of the previously-conducted "water and energy" studies? I cannot answer that. It is troublesome because on the one hand, we have documented evidence of the increasing role of groundwater whereas on the other hand, we have continual "energy and water" assessments that examine only surface supplies. There clearly is a need for a more realistic treatment of groundwater--an alternative to the traditional surface supplies under review and a potential solution to this dilemma of future shortages (translated to mean restrictions and constraints to energy development).

#### The "Water And Energy" Question Revisited

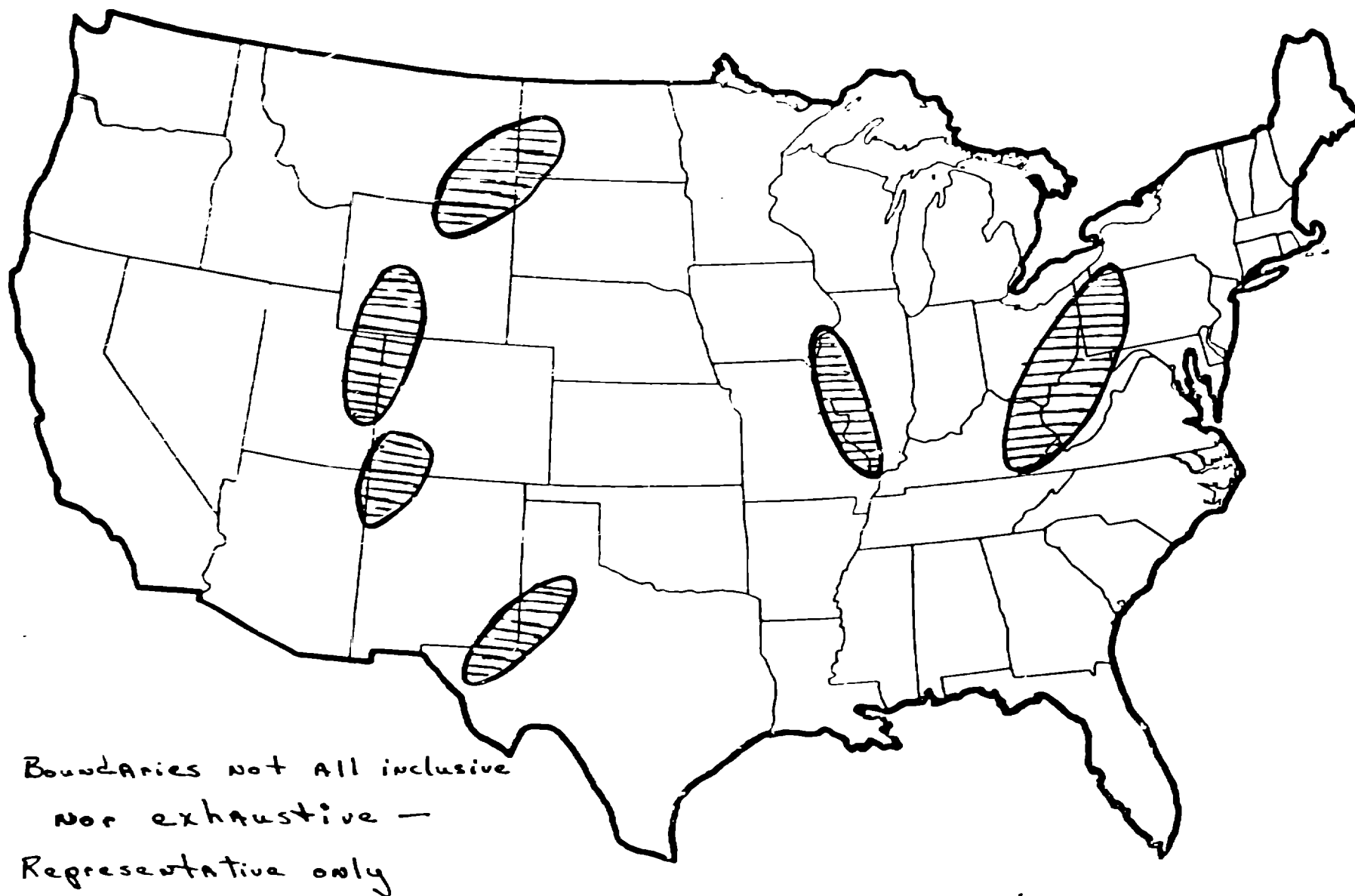
Before turning to a discussion of the more attractive attributes of groundwater, I will present a series of maps. These highlight many of the things addressed earlier and focus attention on why groundwater (1) must play a larger role in meeting energy's ever-increasing demand for water, and (2) its explicit recognition in DOE's assessment of the availability of water to meet any given supply scenario--whether national, regional, or even plant-specific in scope.

The first figure in this series, Fig. 3, portrays the regions of the country where energy resources are expected to play a major role in meeting our needs through the close of this century. These regions are certainly not



Figure 3

# ENERGY RESOURCE REGIONS



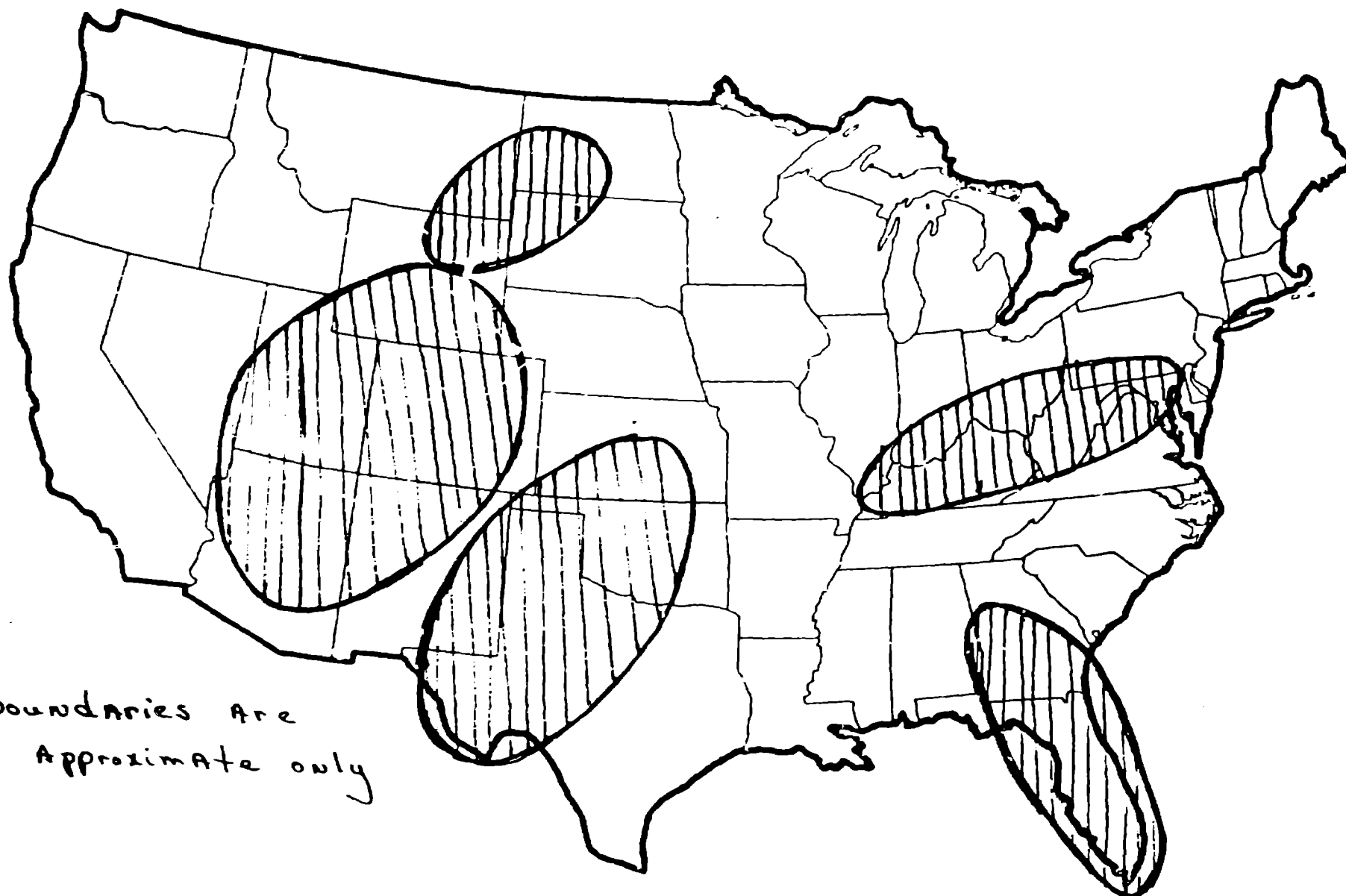
exhaustive, but do define geographical boundaries of areas where near- and mid-term energy activity will be intense. These regions include such present and future energy activities as coal mining (both surface and ground), uranium mining and milling, mine-mouth electrical generation, and synfuels conversion. Here, in these regions, we would expect to see the greatest need for new water to meet energy demands. Here, we could expect the needs of energy for that water to be met in the most opportune way.

Figure 4 geographically depicts regions of the US where present or near-term surface water availability is in serious question. Most studies (all of those reviewed by Dr. Hudson or appearing in Fig. 1) and including the recently released '75 Assessment conducted by the US Water Resources Council, have generally agreed on the location of those regions now experiencing or expecting the most severe shortages--shortages defined by the shortfall of water supplies (principally surface flows plus reservoir storage) to meet present or projected demands. There is nothing new in the identification of these regions, only the precise boundaries may differ from one assessment to another. Surely these regions warrant increasing concern as any economic or demographic growth occurs within their boundaries.

Regions of high groundwater use today are portrayed in Fig. 5. This is certainly not an exhaustive description or listing of all regions with high groundwater use, but does recognize those regions almost always singled out for discussion in water resource evaluations. Although not all of these regions are presently experiencing large overdraft or other associated problems, it could reasonably be expected that regions with high groundwater use today will warrant attention as we proceed into this decade. Problems experienced in these regions where groundwater is being extensively mined include (a) falling water tables, resulting in higher pumping costs and/or

Figure 4

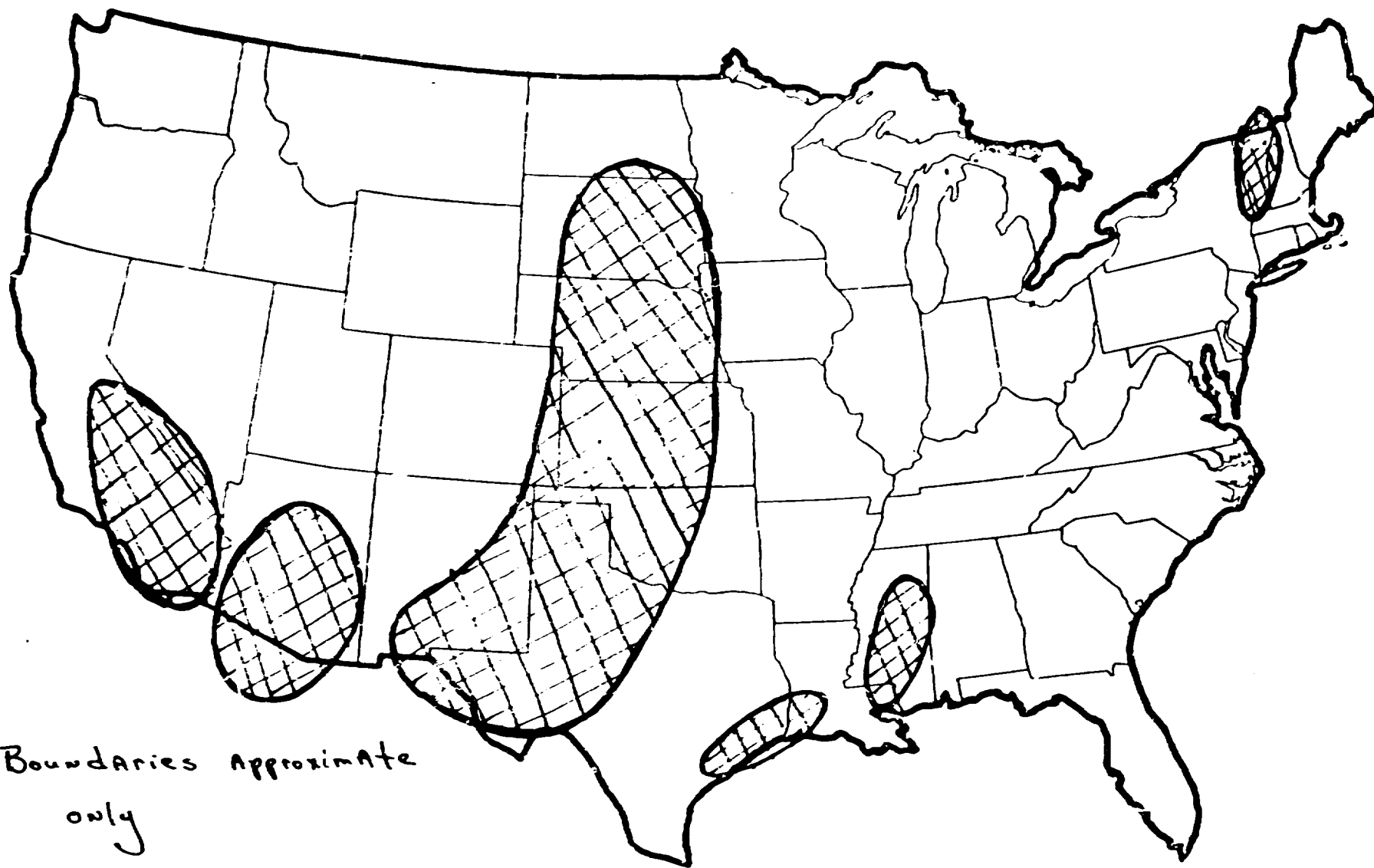
# SURFACE WATER PROBLEM REGIONS



Boundaries are  
Approximate only

Figure 5

# HIGH GROUNDWATER USE REGIONS



Boundaries Approximate  
only

wells being removed from production, (b) degradation of relatively fresh aquifers, and (c) salt water intrusion. It is in these regions that future groundwater use may be the most restricted, implying that other options for supplies must be found. Groundwater supplies in these regions do not offer what may be termed an "attractive" alternative to traditional surface waters for energy. (Groundwater may be considered the traditional source of water in some of these regions.)

By examination of Fig. 6, an overlay of Figs. 3 and 5, one can readily see that the regions experiencing (or projected to experience) the most severe groundwater problems do not coincide generally with the principal energy resource regions. Therefore, energy's potential role in intensifying conflict and competition for groundwater in these regions is minimal.

Figure 7, a composite of Figs. 3 and 4, visually portrays the key reason I believe groundwater offers the US a partial solution to the "water and energy" question. The figure also geographically highlights why most past analysis of the "water and energy" question has reached the conclusions that it has. All studies reviewed to date (Dr. Hudson's discussion and those listed in Fig. 1) have consistently concluded that surface availability cannot and will not meet all of the increased demands to be placed upon it for energy development. Further, from this map it is easy to draw those frightening observations about the future of energy development so frequently contained in our popular literature and press. No other conclusion than increasing "shortages" could be drawn from such an overlay analysis.

Groundwater most assuredly offers a very attractive alternative to the use of traditional surface waters in those regions depicted in Fig. 7. It is here that groundwater should be viewed as a very viable solution to the perceived "water and energy" problem. This is not to say that groundwater is

Figure 6

ENERGY RESOURCE REGIONS  
VS  
HIGH GROUNDWATER USE  
REGIONS

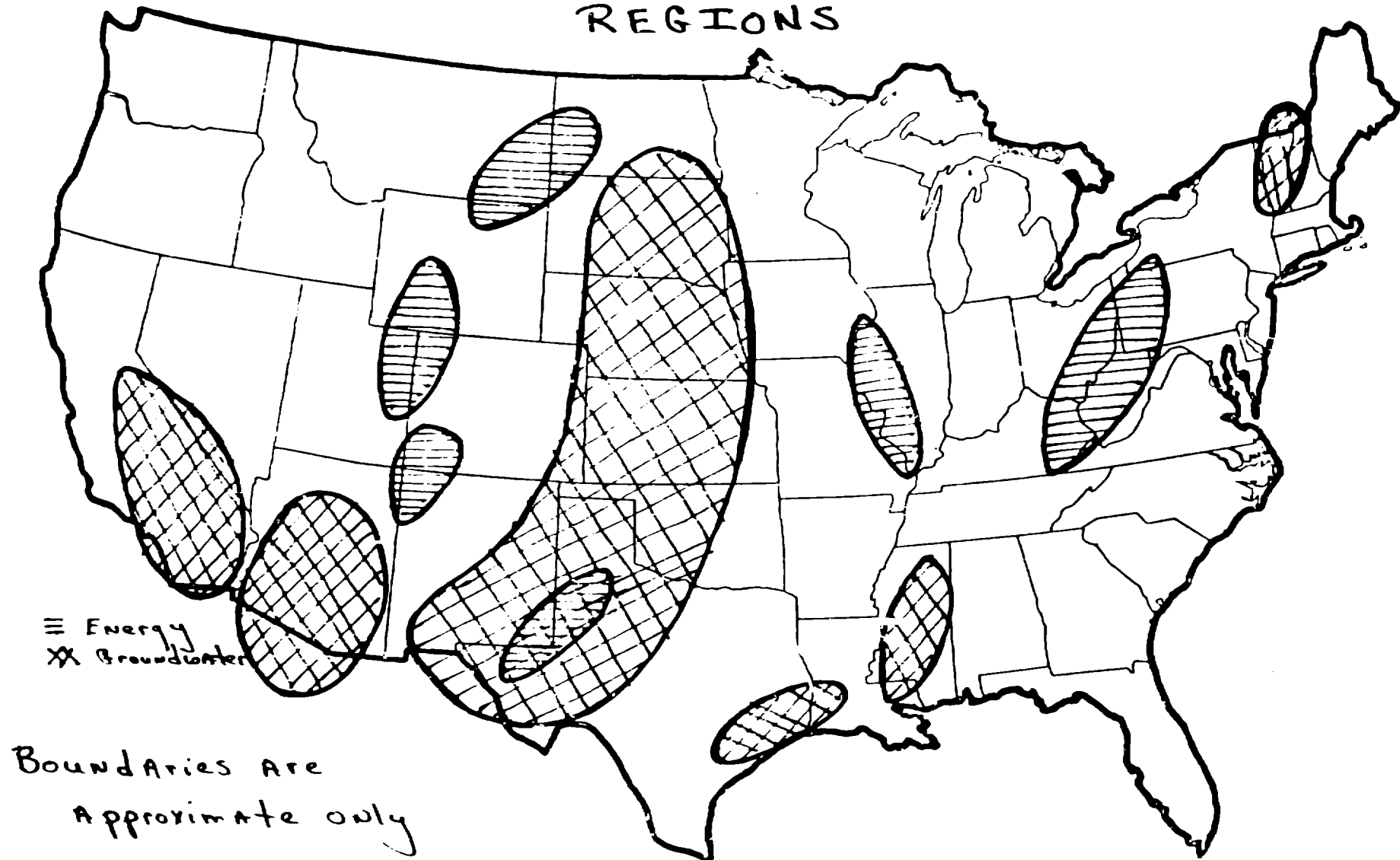
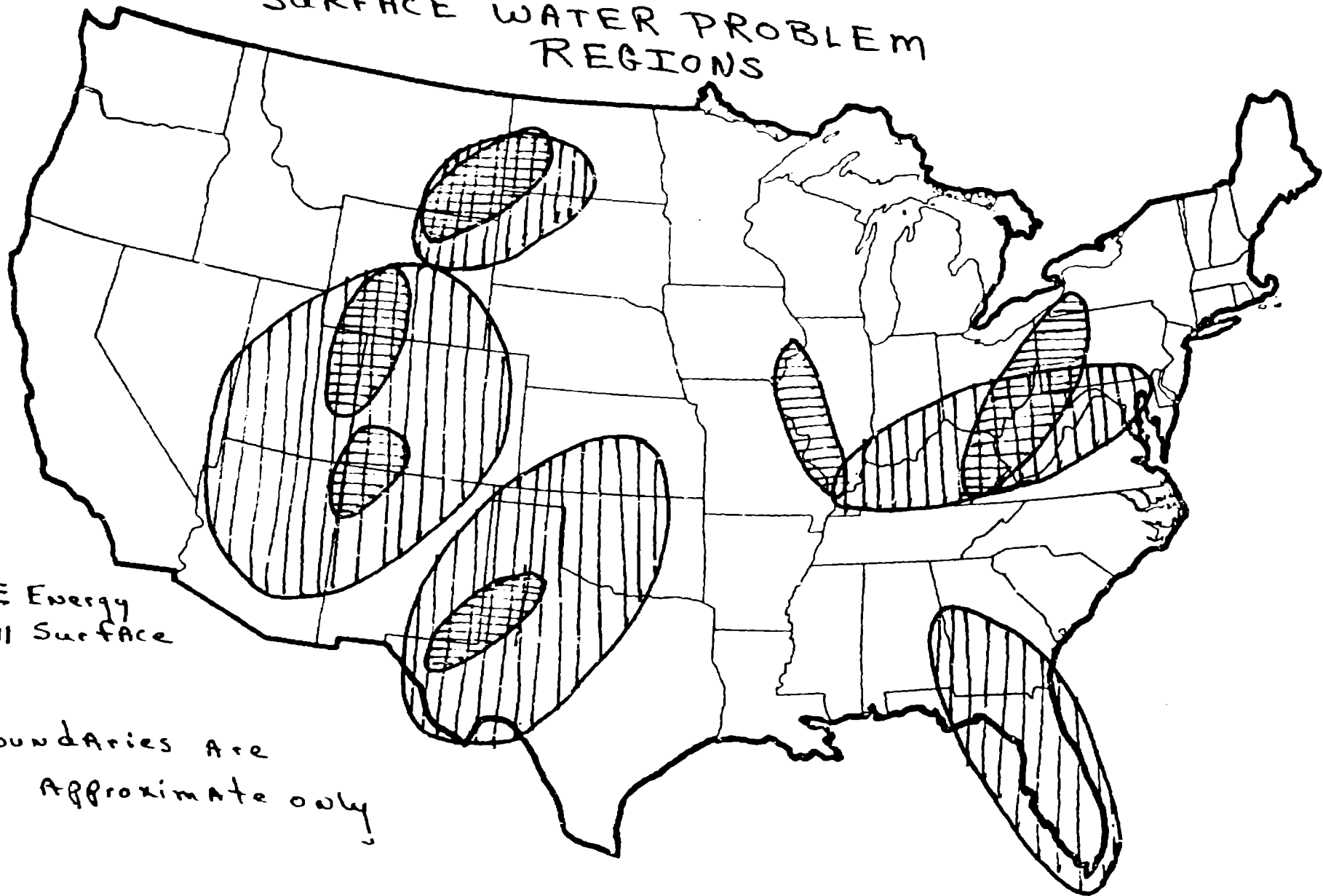


Figure 7

ENERGY RESOURCES REGIONS  
VS  
SURFACE WATER PROBLEM  
REGIONS



≡ Energy  
||| Surface

Boundaries Are  
Approximate only

not without problems; but that with such severe surface problems, concerns, and issues, the groundwater option should be considered very carefully. Groundwater must be included as an alternative to the present surface flow option (committed or uncommitted) in future "water and energy" assessments. By such inclusions concerns over and questions about water availability would most likely be reduced, and the ensuing discussions on potential water shortfalls would be far more informed as to supply options to be exercised by the energy industry.

Two types of groundwater that may offer a solution time and again to the "water and energy" problem defined for much of the West is that of saline groundwater and deep groundwater--both saline and fresh. Figure 8 contains a partial picture of known aquifers with either characteristic. These resources are vast, have been acknowledged as potential sources of water supply for energy production, and, at present, energy has few other competitors for these groundwaters.

More promising is the fact that many of the aquifers underlie those regions where energy resource development is most intense and/or the surface water problems are most severe. Figure 9, an overlay of Figs. 3 and 3, graphically shows the geographical overlap between energy resource regions and regions with either saline or deep groundwater resources.

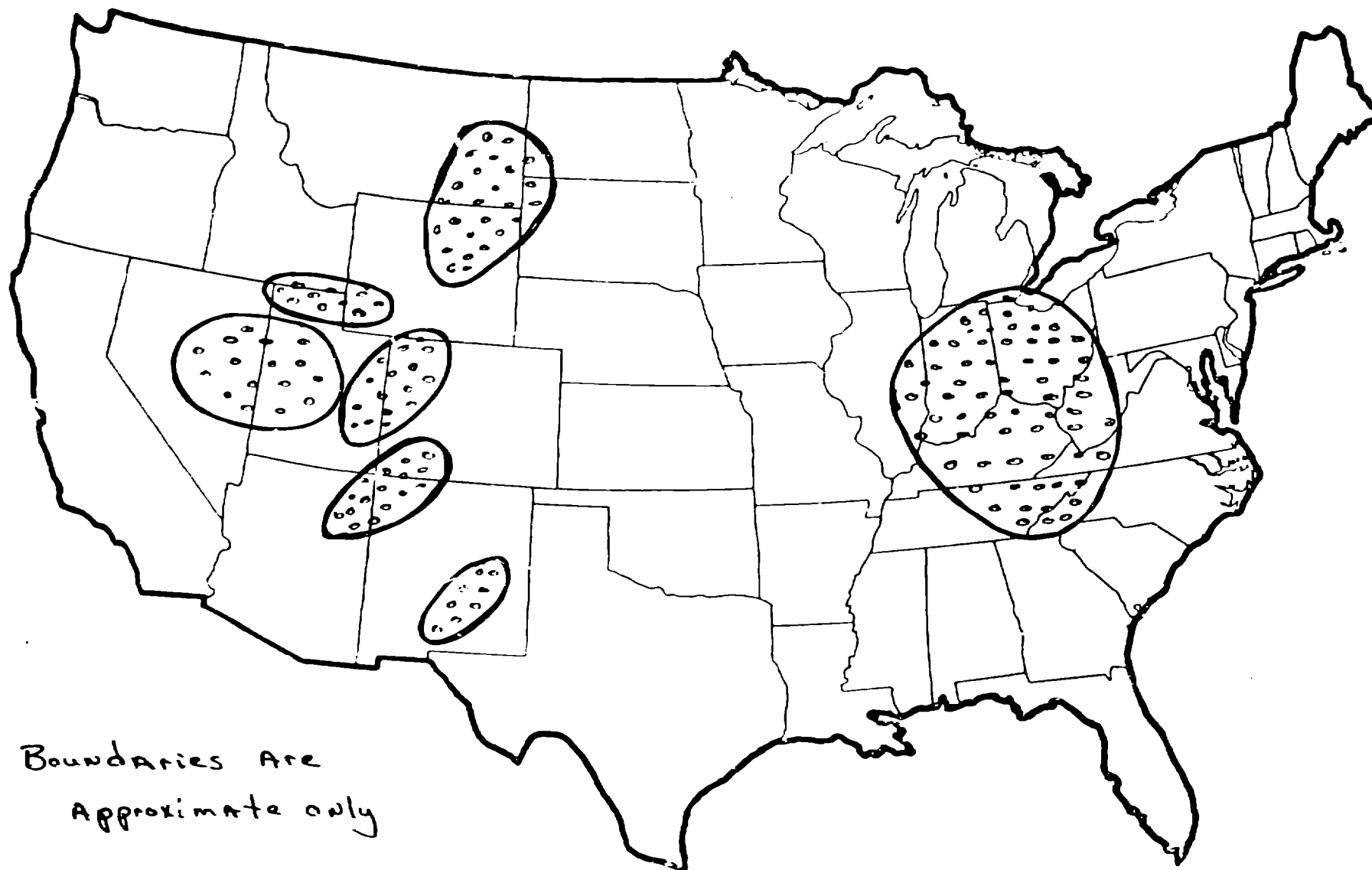
Both prime synfuels development areas in the East are partially underlain by saline groundwater. Portions of the Ohio River Basin have been identified as likely areas of future problems with surface water flows. Saline groundwater resources must receive increased exposure in ongoing and future assessments addressing water availability for synfuels.

The Four Corners region of Northwest New Mexico and Southwest Colorado has been studied extensively during the past 5-8 years. It is here that the



Figure 8

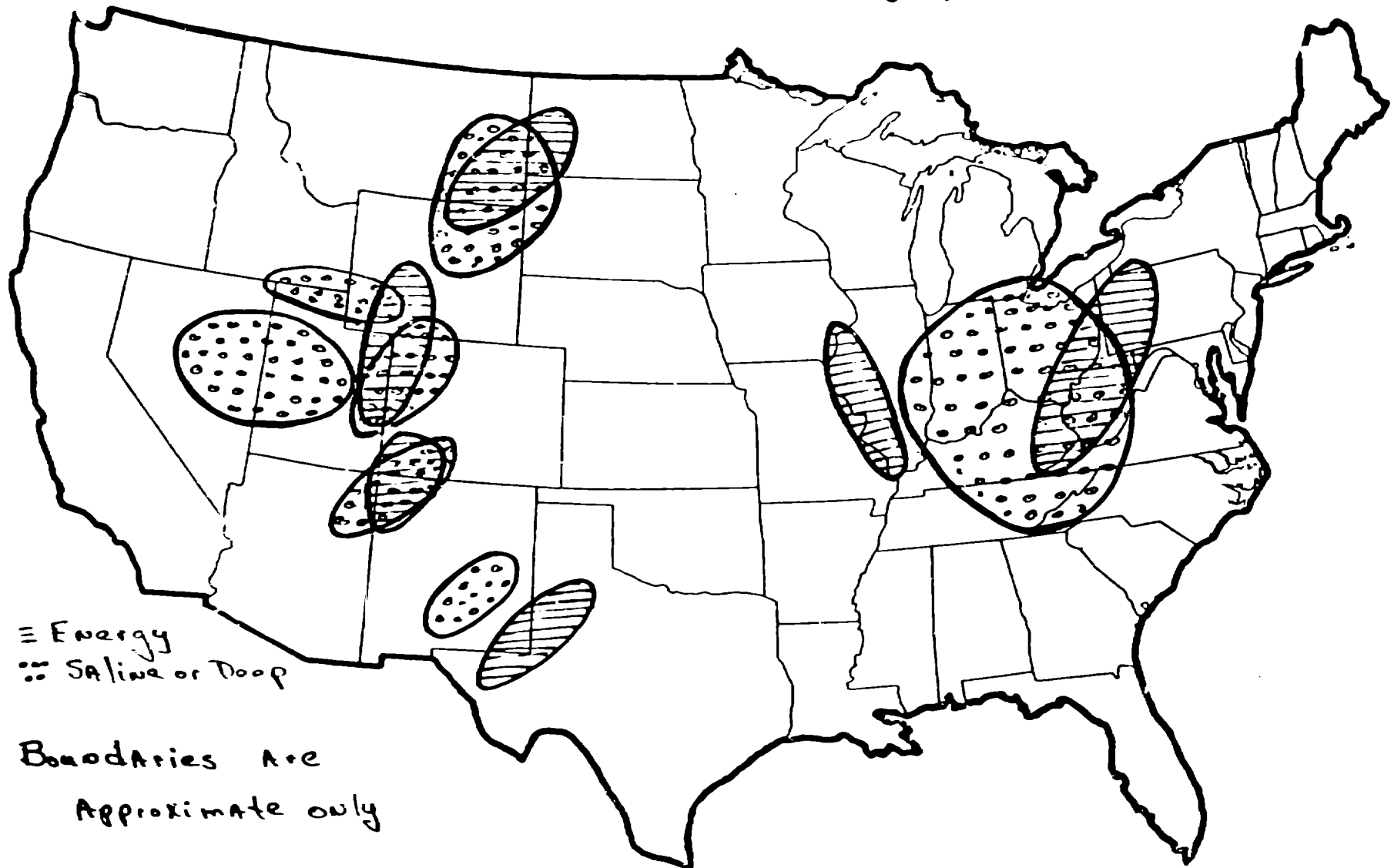
SALINE AND DEEP WATERS



Boundaries Are  
Approximate only

Figure 9

ENERGY RESOURCE REGION  
vs  
SALINE AND DEEP WATERS



water availability question for energy has been a key consideration in conclusions reached to date on capacity limits to energy facility sites. The host of surface water concerns most often voiced are present in the region: seasonal flows, total physical quantities available for new appropriation or transfer, interstate compact restrictions, the interpretation of court-determined allocations, Indian water rights, and Federal reserved rights. All of these issues must be considered when energy companies attempt to acquire surface flows (including storage at the Navajo Reservoir) to meet their needs. Little is known about the total quantities and firm yields of the saline (or least low quality) aquifer underlying much of the energy resource region. But the potential for groundwater use may be a very promising alternative to the apparent dilemma facing energy companies in the Four Corners Region. The energy industry may very well find groundwater the most "attractive" water supply option available to meet its future needs. The groundwater option should be taken seriously by DOE in any further assessments of energy in this region. Before discussing the need for further examination of this groundwater option, we should address the nature of the groundwater resource itself.

#### Groundwater As A Resource

To the extent that groundwater is viewed as a resource, it will continue to be viewed as an "attractive" one. It will offer a promising option to the questionable surface water flows in much of the troublesome energy resource regions. Groundwater may lessen significantly the political and/or institutional hassles and associated costs of acquiring water supplies and may be more easily obtainable than surface flows, especially if these flows are in short supply. It is in this sense that groundwater can be viewed as a resource to be seriously considered by energy.

If, however, groundwater is viewed as a scarce resource, then that supply option will be subject to the same questions, problems, concerns, and issues as the surface waters of today. Competition for its use will result in severe conflicts, forcing the energy industry into similar positions facing it today in its endeavor to acquire scarce surface flows. As portrayed by Fig. 5, any attempt to use large quantities of groundwater in certain regions will be subject to serious review. In addition, the use of fresh groundwater by energy in many regions is likely to be closely examined, thereby giving rise to the same problems facing the nation now under this generic "water and energy" question. Groundwater cannot be viewed as an "attractive" option if it is viewed as a scarce resource.

We do not have answers yet regarding which groundwaters of the US can be viewed principally as resources. The more aquifers that can be placed into that category, the less one would expect to hear of the "water and energy" question. To be sure, there are some present groundwater classifications that appear on the surface to be good candidates for the resource category. These types of groundwaters today offer an "attractive" option that is now or will be exercised to meet energy's water needs. Two of the more obvious examples are saline waters in either shallow or deep aquifers and the deep aquifers (both fresh and saline) underlying some of the key energy resource regions. Saline aquifers do not usually have other potential claimants for their use. Energy, for a number of reasons, can employ this water supply to meet many of its needs at acceptable costs. (We will not get into an examination of what are acceptable costs at this time.) Agriculture, the largest user of water in the West, is not likely to make use of these saline aquifers because of poor water quality and the consequential costs on production. Municipal systems generally will pursue higher quality water for their use. Other industrial

interests (nonenergy) have made use of saline waters, but the number of these interests in the energy resource regions are few. Thus, energy development becomes the prime activity that could easily use saline waters to meet its needs.

Another emerging example of "attractive" groundwaters is mine dewater. In the uranium belts and, to some extent, in the coal and oil shale regions of the West, a significant quantity of groundwater must be taken from a mine before production can begin. Further, dewatering must take place on a continuous basis throughout the life of many of these mines. The removed water is contaminated in a number of instances, and therefore cannot readily be used by others. In New Mexico, up to 100,000 acre-ft a year are removed as dewater from uranium mines. In Wyoming, tens of thousands of acre-ft are being removed from uranium mines. As insitu production technology is adopted for coal and oil shale conversion, there could be large quantities of dewater available for use by others. Mine dewater, then, is a water supply option that should be included in future assessments of energy, especially as it relates to the "water and energy" question.

Conjunctive use management of surface and groundwaters has been advocated for at least 20 yr. Here, groundwater is treated as both a supplement and complement to the traditional surface supplies. Many shallow aquifers in the country, and especially in the energy resource regions, are integrally connected to streamflows. Scarce surface flows may be augmented by proper management and subsequent use of these shallow groundwaters. Present surface users (owners) would benefit, and energy could benefit through release of the same surface flows for its use during portions of the year. The National Commission on Water (1973), the National Commission on Water Quality (1975), an enumerable set of articles in such journals as Water Research, Water

Resources Bulletin, and Groundwater, as well as a host of technical and policy publications by the US Geological Survey have advocated the adoption of conjunctive use management as one of the most efficient and cost effective ways to increase water availability. Energy has already participated in several applications of that policy, and is in an excellent position to promote its future use. Thus, groundwater again offers a very "attractive" alternative and partial solution to the "water and energy" dilemma professed to exist in parts of the US.

#### Saline Waters

Figure 10 lists a few thoughts on the use of saline water for energy. Its use has been examined quite extensively in the past. Desalting technology was heavily pushed by the Office of Water Research and Technology (OWRT) in the late '60s and '70s. From these studies, much was learned about saline water's general location, its general characteristics, and the cost of making it usable or fresh. The dual plant concept, that is, simultaneous production of power and fresh water, has been examined for a number of regions--both nationally and internationally. Its (saline waters) use for cooling many times was part of the proposal.

The technical feasibility of using saline water in some energy processes has been shown by studies and demonstrated in a few cases. As stated above, there are a large number of studies addressing the use of saline water for industrial and energy-related activities. Through process engineering design, saline water supplies were worked into the facility with generally minimal configuration change and cost additions.

Sea water has been used for both cooling and internal process needs by energy. The technical feasibility of its use is no longer questioned, only

## FIGURE 10

### USE OF SALINE WATER

TECHNICALLY FEASIBLE FOR SOME PROCESSES

PAPER STUDIES - PROCESS ENGINEERING

SEA WATER UTILIZATION

INTERNATIONAL EXAMPLES

ECONOMICALLY ACCEPTABLE

MAY BE LESS EXPENSIVE THAN DEVELOPMENT OF  
SURFACE SUPPLIES

ADDS LITTLE TO PRODUCT PRICE

LESSENS "POLITICAL" AND "TRANSACTIONS"  
COSTS

its costs. Saline waters are higher quality than sea water, thus their use by energy also would appear to be technically feasible by inference, if not by actual demonstration.

We know by its present use that saline water is economically acceptable. Moreover, both of the recently completed Sec. 13(a) studies--Upper Colorado and Upper Missouri--have stated that it may be less expensive to use groundwaters (saline or slightly saline usually) for energy's needs than to develop surface supplies for either basin. Here we have the growing recognition of the "value" of groundwater for energy development.

Because the use of saline water (or any groundwater for that matter) appears to add little to product price, its "attractiveness" is measurably enhanced. This is especially important for energy, because exercising this option to meet energy's needs can take place without fear of large cost penalties. Moreover, real cost savings may result if exercising the saline water option lessens the "political" and "transactions" costs of water acquisition. Competition for scarce surface supplies is decreased, conflicts over water availability are reduced, and the general institutional climate facing energy in its quest for water supplies does not have to be tested. Rather, it may be that use of saline waters facilitates institutional acceptance of energy in some regions.

To pursue this economic question for a moment, even if saline waters (or the more general category of groundwater) were measurably more expensive in terms of process engineering costs, it is still possible that it may pay energy to choose this supply option. States have a great deal of control over their waters and make their acquisition and use subject to a number of legal, administrative, and institutional considerations. These considerations may result in delays, large indirect costs, and increasing tensions between



interest groups and the energy development itself. Use of saline waters by energy may go a long way in promoting federal/state cooperation in the water availability area. Total costs of pursuing the groundwater option are likely to be only slightly more (if not less) than the use of surface supplies. An immeasurable amount of goodwill may be fostered, which would result in a more conducive atmosphere for future energy development.

Returning to this notion of the technical feasibility of using saline waters for energy, Fig. 11 lists a few agencies that have commissioned studies to date. DOE has funded several, the most notable being that of the Radian Corporation of Texas and the Water Purification Associates of Massachusetts. Both of these studies have identified principal saline aquifers that might be used, and have addressed the costs and cost penalties of using saline water in the production of energy. Technical changes to present water use designs and their cost implications were carefully evaluated. The Electric Power Research Institute and the Nuclear Regulatory Commission have addressed the use of saline water for energy: first from a technical standpoint, and second from its cost impact. There have been a number of master's theses and Ph.d. dissertations that have examined the technical feasibility and costs of saline water use for energy. All of this information generally does not contradict the previous statements on saline water's technical feasibility.

Saline water can be used for cooling and electricity generating facilities require huge amounts of water for cooling purposes. Depending upon its input quality, saline water can be used with little additional cleanup than is presently the case for higher quality make-up water. Cycles of concentration must be decreased, of course, but saline water can be used as a substitute for present sources. If the quality is too bad, additional treatment will be necessary before sending it to the cooling towers. But its potential use for cooling is not readily questioned.

FIGURE 11

SALINE WATER STUDIES  
(ADDRESSED TECHNICAL AND COST FEASIBILITY)

RADIAN CORPORATION

WATER PURIFICATION ASSOCIATES

STUDIES FUNDED BY EPRI

STUDIES FUNDED BY NRC

STUDIES FUNDED BY IAEA

UTAH WATER RESEARCH LABORATORY

NUMEROUS THESES AND DISSERTATIONS

Air pollution control equipment--especially flue gas desulfurization technology--and the disposal of wastes, do not require extremely high quality water. Therefore, blowdown from cooling towers and saline make-up water are ideal supplies. The electricity generating sector, then, could make greater use of saline waters without greatly affecting its basic design process or its costs of production.

The synfuels technologies also have been examined, with the result that saline waters could be used in a number of ways. Certainly, relatively low quality water could be employed for cooling, air pollution control, and waste disposal. For a number of conversion processes, themselves, it was found that saline water would be acceptable, albeit at a cost. Mining already uses saline water sources to meet its needs in many regions, with great potential for broader use in the future. And, of course, slurry pipelines appear to be prime candidates for saline water employment in the movement of coal. Figure 12 summarizes some of these uses where technical feasibility (and cost acceptability) have been addressed.

#### Deep Waters

Deep aquifers offer an alternative source of water supply for much of the energy industry. Getting to these aquifers has already been demonstrated technically. The oil and gas industry employs drilling technologies that are capable of reaching even the deepest of aquifers. We also know from the oil and gas industry that water can be pumped from these deep aquifers. However, we know that today it is generally considered uneconomical or less than practical to do so. Why sink a well 10,000 ft or so when agricultural water is available for transfer? When one is speaking of \$40-100/ft per well, the deep groundwater can be very expensive.

## FIGURE 12

### TECHNICAL FEASIBILITY OF SALINE WATER USE

COOLING WATER SYSTEMS

AIR POLLUTION CONTROL SYSTEMS

WASTE DISPOSAL

CONVERSION PROCESS MODIFICATIONS

GASIFICATION

LIQUEFACTION

MINING

SLURRY PIPELINES

The economics of this situation will change over time, with the real cost of this option coming closer to the costs of other available options. It already may be true that the "political" and "hassle" costs (and this includes all of the uncertainties about availability) of surface supplies may surpass the dollar costs of using deep aquifers in some regions of the US. The firm supply of water may be valued quite highly, with deep aquifers offering the greater probability of success over a 30-yr time horizon. By merely skirting the political issues of surface availability and surface water's use for energy, deep aquifers offer an "attractive" alternative and partial solution to this ever-present "water and energy" question. A summary of some positive characteristics for deep aquifers are displayed in Fig. 13.

#### Promising Institutional Arrangements

There are some promising institutional arrangements emerging for better use of our nation's groundwaters. In Texas, conservancy districts have been established as local management agencies that can and do control pumping. Allocation of the groundwater resource is made to both maximize its use by all and to ensure a continuous supply over some time period. This sort of arrangement, although usually to benefit agriculture and municipal systems, helps increase the potential yield of aquifers, thereby hopefully making these waters more available for energy.

Mentioned earlier was the conjunctive use management of surface and groundwater. Also mentioned was the fact that energy has already been a participant in its institutional exercise. Although groundwater has been viewed as the supplemental supply source in these arrangements, they have nonetheless provided access to waters that may not have been available before. As conjunctive use management is adopted in more areas, energy's access to previously foreclosed water supplies should increase.

## FIGURE 13

### CHARACTERISTICS OF DEEP AQUIFERS

TECHNICALLY FEASIBLE

ECONOMICALLY QUESTIONABLE

SUPPLY ALTERNATIVES

DEMAND REDUCTIONS

ECONOMICALLY ATTRACTIVE

FIRM SUPPLY

POLITICS

There are a variety of groundwater sources that may be tapped by energy. Many of these depend only upon energy becoming an active partner in their development. Subsurface water beneath irrigated lands offers but one opportunity for the energy industry. By proper extraction (drainage in this case) of the saline water, both agriculture and energy would benefit: agriculture, because this would reduce the salt intrusion problem so prevalent in a large number of irrigated regions; and energy, because it would acquire access to a useful supply of water not generally acknowledged as being available in the past.

It is also not unthinkable that energy could develop aquifers (provide a source of water) for both domestic and agricultural use in portions of the US in addition to meeting its own needs. Codevelopment, or single development with domestic and agricultural access to the water supplies, of groundwater aquifers could go a long way in helping energy acquire adequate supplies of water to meet its future needs. Political acceptability of energy's use of water should be enhanced, with institutional (regulatory and administrative) climates becoming more favorable. By working in concert with nearby communities to meet their water needs, the idea of energy development next door might become more palatable and less susceptible to political pressures.

Although I have no new thoughts on what course these emerging institutional arrangements might or should take, I do believe that energy stands only to benefit from its participation. New water sources may open up, thereby lessening competition for and conflict over other scarce supplies, and present options may be easier to exercise. These new institutional arrangements and the groundwater sources involved in their specification cannot be ignored by future water availability assessments.

## Conclusion

To conclude this rather lengthy and divergent discussion on groundwater and why it must be viewed as an "attractive" alternative and partial solution to traditional surface supplies, I would like to share some views on recent statements made by DOE personnel. I have obtained copies of testimony and/or speeches made by John O'Leary and James Slessinger in 1978, and by Ruth Clausen during the past 4-5 months. In their testimony or speeches, the generic "water and energy" question was raised with respect to water availability for energy. Although the response by each differed, two basic concerns were voiced throughout. The first is that energy policy must be coordinated with and consistent with water policy in this country. The second concern is that energy results in no adverse environmental impacts, and here environmental is defined broadly enough to include the issue of water availability.

Groundwater, or at least its consideration as a supply option, will play an increasingly important role in providing positive opportunities to lessen both these concerns. Proper information must be gathered on groundwater availability, its costs, and its institutional climate in order for it to be evaluated for use by the energy industry. Ongoing and all future assessments must take note of the groundwater option. This option must be factored into the water availability analysis if the assessment results are to have meaning and, more importantly, are to be relied upon in helping to formulate energy policy. Water shortages for energy and conflicts with present users must be recognized for what they are--potential trouble spots for the siting of energy facilities. Information on these troubling locations must be correct and must not provide misleading conclusions about any one region's potential contribution to this nation's energy supply.



Groundwater has offered and will continue to offer an "attractive" alternative and partial solution to the question of water availability for energy in the US. Such acknowledgment must be included in DOE's evaluation of the generic "water and energy" question.